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(71) Applicant (for all designated States except US): TERA-COM AB [SE/SE]; Box 17666, S-118 92 Stockholm (SE).

(72) Inventor; and
(75) Inventor/Applicant (for US only): HAGGÅRD

LJUNGQUIST, Jonas [SE/SE]; Spångavägen 70, S-168 75 Bromma (SE).

(74) Agents: BERGENTALL, Annika et al.; Cegumark AB, Box 53047, S-400 14 Göteborg (SE).

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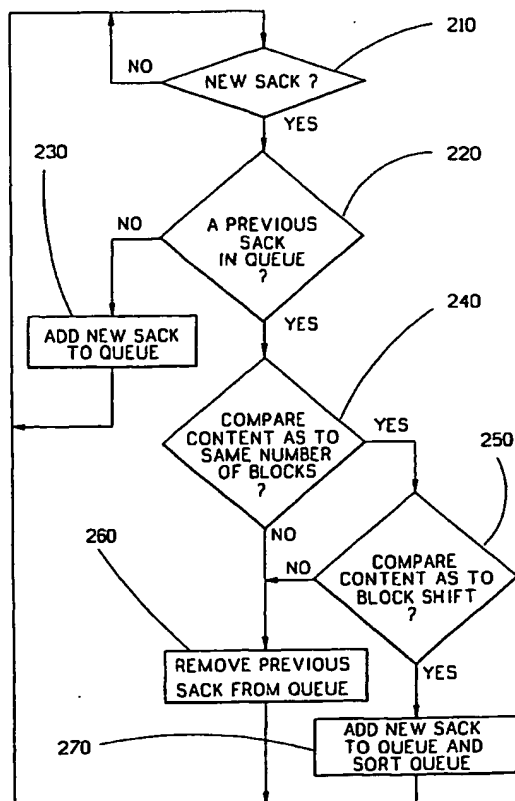
(57) Abstract: A method of efficiently using Transmission Control Protocol (TCP) with Acknowledgements (ACKs) comprising Selective Acknowledgement (SACK) options in asymmetrical networks by reducing the number of ACKs with SACK options to be transferred back to a sender. New ACKs with SACK options are compared to previous ACKs with SACK options as to their content, and in dependence of the comparison, i.e. if the previous ACK with a SACK option comprises redundant or invalid information and no additional information in relation to the new ACK with a SACK option, then the previous ACK with the SACK option is removed and not sent back to a sender.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

5   Method for flow control

TECHNICAL FIELD

10   The present invention generally relates to a method of
     handling   asymmetrical   transmissions,   specifically
     information transported by means of transmission control
     protocol (TCP) via asymmetrical error prone channels.

15

     BACKGROUND

     A demand for mobile high capacity data transfers have put
     high capacity, but unfortunately asymmetrical, wireless
20   broadcasting transmission channels in focus. The majority
     of all information transfers today are made with the help
     of Transmission Control Protocol (TCP). Unfortunately this
     protocol   is   not   designed   for   neither   asymmetrical
     transmission or wireless error prone transmissions, such as
25   Digital   Audio   Broadcasting   (DAB),   Digital   Video
     Broadcasting Terrestial (DVB-T), and Wavelan. Due to this
     there has come about many different suggestions such as
     replacing TCP with other modern protocols and modifying TCP
     to different varying degrees.   For information/data
30   transfer via wireless transfer channels special measures
     have to be taken to be able to manage a low as possible
     transmitting power. The measures can, for example, be the
     use of error correcting codes or special retransmission
     protocols.
35

     To be able to handle bit errors with TCP, a Selective
     Acknowledgement (SACK) option to Acknowledgements (ACKs)
     have been developed. By means of the SACK option the TCP

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transmitter can get to know which packets/segments after
the first lost segment that have reached their destination.
A SACK option can normally give information of up to three
contiguous blocks of segments that are correctly received
5 and also three contiguous blocks of missing or erroneous
segments in the information transmission. The use of SACK
options presupposes that there is no significant asymmetry
in the network so that as many SACKs as information
segments transmitted downlink, can be transmitted uplink.
10

One way of dealing with asymmetry in an extremely
asymmetrical network is called ACK-filtering and works on
the principles that many of the ACKs that are transmitted
back to the transmitter are redundant and do not have to be
15 transmitted.   If there is a limitation in the return
channel there will emerge a queue and it is in this queue
that the ACK-filtering operates.

A combination of these two methods will create problems.
20 SACK options are based on the assumption that there is no
limitation in the return channel, and they are thus
designed accordingly, and if an ACK-filtering is operated
on a SACK queue, i.e. a queue of ACKs with SACK options,
then some SACK blocks will be completely removed and then
25 the transmitter will not find out that these blocks have
been received.   This will lead to the transmitter
erroneously retransmitting the segments in these blocks
that have already been received. This will result in the
downlink transmission channel suffering when bandwidth is
30 used for unnecessary retransmissions.

The problems associated with asymmetrical networks in
conjunction with TCP needs to be solved satisfactorily.
TCP can handle an asymmetry factor of 50 times the downlink
35 to the uplink in most common implementations.   Future

networks can have an asymmetry factor of around a 1000
times. There seems to be room for improvement.

5   SUMMARY

An object of the invention is to define a method for
efficiently transferring information in an asymmetrical
network.
10
Another object of the invention is to define a method of
efficiently using TCP with ACKs comprising SACK options in
an asymmetrical network.

15 The aforementioned objects are achieved according to the
invention by a method of reducing the number of ACKs with
SACK options to be transferred back to a sender. New ACKs
with SACK options are compared to previous ACKs with SACK
options as to their content, and in dependence of the
20 comparison, i.e. if the previous ACK with a SACK option
comprises redundant or invalid information and no
additional information in relation to the new ACK with a
SACK option, then the previous ACK with the SACK option is
removed and not sent back to a sender.
25
The aforementioned objects are also achieved by a method
of, when receiving information in a network that transports
information according to the general principles of the
Transmission Control Protocol (TCP), reducing the number of
30 selective acknowledgements (SACKs) to be transferred back
to a sender. Selective Acknowledgements, SACKs, will
generally be used for referring to Acknowledgements (ACKs)
with Selective Acknowledgement options. The method
comprises a plurality of steps when a new selective
35 acknowledgement has been triggered/generated. In a first

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step determining if there is a previous selective acknowledgement in a queue to be transferred to the sender, and if there is a previous selective acknowledgemnt in the queue then further performing the following additional

5   steps. In a first additional step comparing the content of the new selective acknowledgement with the content of the previous selective acknowledgement. Finally in a second additional step removing the previous selective acknowledgement from the queue in dependence on the result

10   of the comparison.

Advantageously in the second additional step of removing the previous selective acknowledgement from the queue, the previous selective acknowledgement is removed from the

15   queue if the previous selective acknowledgement has a different number of blocks than the new selective acknowledgement. Further in the second additional step of removing the previous selective acknowledgement from the queue, the previous selective acknowledgement can and/or

20   also advantageously be removed from the queue if the previous selective acknowledgement has the same number of blocks as the new selective acknowledgement and if only the right edge of the first block is different between the previous selective acknowledgement and the new selective

25   acknowledgement.

In some versions of the invention the method can further advantageously comprise the additional step of sorting the selective acknowledgements in the queue as to which blocks

30   are redundant. Preferably the step of sorting comprises the following four block sorting steps. A first block sorting step of disassembling into blocks the selective acknowledgements that have not been transferred to a sender. A second block sorting step of removing redundant

35   blocks. A third block sorting step of assembling the

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remaining   blocks   into   block   sorted   selective
acknowledgements. A fourth block sorting step of placing
the block sorted selective acknowledgements into the queue.
The new selective acknowledgement is preferably not
5   disassembled, but the knowledge of which blocks are
comprised in the new selective acknowledgement is used in
the second block sorting step for removing redundant
blocks. In some versions there are status indicators to
keep track of one or both of if and when a queue has been
10   sorted with regard to selective acknowledgements.

The step of sorting can in some version of the method
alternatively   comprise   the   following   two   selective
acknowledgement steps. A first selective acknowledgement
15   step of comparing the selective acknowledgements that have
not been transferred to a sender. A second selective
acknowledgement step of removing the redundant selective
acknowledgements, i.e. removing selective acknowledgements
only comprising redundant blocks that are included in other
20   selective acknowledgements.

In some versions of the method the step of sorting is
performed only if the previous selective acknowledgement
has not been removed from the queue.
25

Preferably the method is performed on the output queue in
any suitable layer from the TCP layer to the link layer,
specifically the method is performed most advantageously on
the internet protocol layer output queue.
30

By   providing   a   method   for   removing   Selective
Acknowledgements (SACKs) from an output queue a plurality
of advantages over prior art systems are obtained. A
primary purpose of the invention is to, in a simple manner,
35   enable the use of highly asymmetrical networks. According

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to the invention this is achieved primarily by making
simple, and thus quickly executable, comparisons between
the contents of new SACKs and previous SACKs and removing
a previous SACK if the content is redundant and/or invalid.
5   There is thus no loss of SACK information which could lead
to unnecessary retransmissions. By reducing the number of
SACKs that have to be sent back, a network with a higher
asymmetry factor can be used. Other advantages of this
invention will become apparent from the description.
10

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described in more detail for
15 explanatory, and in no sense limiting, purposes, with
reference to the following figures, in which

Fig. 1   shows an asymmetrical transmission system,

20 Fig. 2   shows a flow chart of a method according to the
           invention,

Fig. 3   shows the layered architecture of an information
           consumer according to the invention.
25

DETAILED DESCRIPTION

In order to clarify the method and device according to the
30 invention, some examples of its use will now be described
in connection with Figures 1 to 3.

The invention concerns information transfers in networks,
especially asymmetrical networks. Figure 1 shows an
35 asymmetrical transmission network on which the invention is

intended to operate. An information consumer 150 communicates with a first uplink gate 160 which transfers download data requests via a low capacity back channel 170 to a second uplink gate 180 which transfers requests to a

5 connection network 120 such as internet, onto which a desired information provider 110 is connected. The low capacity back/uplink channel 170 might be a telephone network or a mobile cellular mobile telephone network in which case the first uplink gate 160 and the second uplink

10 gate 180 can be modems. After having received the request and information on how to transfer the requested information to the information consumer 150, the information provider 110 will transfer the desired information, if it is available, to the information

15 consumer 150 via the connection network 120, a downlink gate 130 and a high capacity downlink channel 140. The high capacity downlink channel can, for example, be a high capacity broadcasting system such as a Digital Audio Broadcasting (DAB) system, a Digital Video Broadcasting

20 Terrestial (DVB-T) system, or a cable TV network.

As mentioned previously, it is advantageous to use ACKs with SACK options, which will simply be referred to as SACKs. With SACKs an information consumer 150 can inform

25 the sender about all segments that have arrived successfully, so the sender need retransmit only the segments that have actually been lost. A SACK can normally comprise information of up to three contiguous blocks of segments that are correctly received and also up to three

30 contiguous blocks of missing or erroneous segments in the information transmission. The first block of a SACK always relate to the segment that triggered it. Each block represents received bytes of data that are contiguous and isolated, i.e. the bytes below the block (Left Edge of

35 Block minus 1), and just above the block (Right Edge of

8

Block), have not been received. The Left Edge of a Block
is the first sequence number of this block and the Right
Edge of the Block is the sequence number immediately
following the last sequence number of this block.

5

Following is a short example of how an ACK with a SACK
option works. It is assumed that the left window edge is
5000 and that the data transmitter sends a burst of 8
segments, each containing 500 data bytes.

10

Sent	Received/ Trigger	ACK	SACK	option	blocks			
			First Left Edge	First Right Edge	Second Left Edge	Second Right Edge	Third Left Edge	Third Right Edge
5000	5000	5500						
5500								
6000	6000	5500	6000	6500				
6500								
7000	7000	5500	7000	7500	6000	6500		
7500								
8000	8000	5500	8000	8500	7000	7500	6000	6500

20

The first segment, 5000, is received and triggers an ACK
5500 indicating that segment 5500 is not received. The
second segment, 5500, is lost, nothing further happens.
The third segment, 6000, is recieved and triggers an ACK
25 5500 [6000 6500 ; -- ; --], i.e. an ACK with a SACK
option. This indicates to the transmitter that the second
segment is lost and by means of the SACK option that
segment 6000 (bytes 6000 to 6499) has been received and not
segment 6500 and further. The fourth segment, 6500, is
30 lost, no reaction. The fifth segment, 7000, is received

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and triggers an ACK 5500 [7000 7500 ; 6000 6500 ; --].
The sixth segment, 7500, is lost, no action. The seventh
segment, 8000, is received and triggers an ACK 5500 [8000
8500 ; 7000 7500 ; 6000 6500].

5

SACKs presupposes that the network used for information
transfer is fairly symmetrical, i.e. that there is no
practical limitations in the uplink channel 170 for
transferring SACKs back to the sender. In an asymmetrical
10   network according to Fig. 1 an output queue 155 full of
SACKs will form at or around the information consumer 150
or the first uplink gate 160 due to limitations in the
uplink channel 170. This will cause delays in the transfer
of SACKs to the downlink gate 130 and/or the information
15   provider 110. This in turn will also put restrictions on
the transfer of information on the downlink channel 140,
because there are restrictions on how much information is
sent without any confirmation of it being received or not.
There is thus a need to eliminate any unnecessary delays
20   returning SACKs. According to the invention, SACKs are
compared as to their content to determine if they can be
discarded or not. This is preferably performed on the
SACKs in the output queue 155.

25   When the SACKs are compared as to their content three
different cases arise. A first case is when the new SACK
has more blocks than the previous SACK. A second case is
when the new SACK has fewer blocks than the previous SACK.
Finally a third case is when the new SACK has the same
30   number of blocks as the previous SACK.

The first case when the new SACK has more blocks than the
previous SACK, then the previous SACK is redundant and can
be removed. SACKs use a stack principle with push and pop
35   where it always tries to report the latest blocks. This

means that the new SACK will comprise all of the blocks of the previous SACK and one or more new blocks. The previous SACK is thus redundant in that it does not contain any information that is not in the new SACK. For example a

5   previous SACK has been triggered, ACK 10 [18 19 ; 11 17 ; --], segments 20 to 24 arrives triggering a new SACK, ACK 10 [20 25 ; 18 19 ; 11 17], making the previous SACK redundant.

10 The second case when the new SACK has fewer blocks than the previous SACK, then the previous SACK contains old invalid information and can be removed. Because SACKs always comprise the maximum number of blocks that is possible (in most implementations it is three blocks) this means that if

15 the new SACK comprises fewer blocks, then new data has arrived to the receiver and filled one of the holes of data. The previous SACK thus comprises old invalid information and can be removed. For example a previous SACK is ACK 10 [20 25 ; 18 19 ; 11 17], the receiver then

20 receives segment 19 triggering a new SACK, ACK 10 [18 25 ; 11 17 ; --], making the previous SACK redundant.

Finally a third case is when the new SACK has the same number of blocks as the previous SACK. This case needs to

25 be divided into two different events. A first event is when new data is added to the first block. The only thing that is different between the two SACKs is that the first block is different. This means that the previous SACK comprises old invalid information and can be removed. For

30 example a previous SACK is ACK 10 [20 25 ; 18 19 ; 11 17], the receiver receives segment 25 triggering a new SACK, ACK 10 [20 26 ; 18 19 ; 11 17], making the previous SACK redundant. A second event is when new data give rise to a new block. The new block will be put first in the SACK and

35 push out the last block, i.e. the last block will be

shifted out and the previous SACK can thus not be removed.
For example a previous SACK is ACK 10 [20 25 ; 18 19 ; 11
17], the receiver receives segment 28 triggering a new
SACK, ACK 10 [28 29 ; 20 25 ; 18 19], i.e. the previous
5 SACK comprises information about segments 11 to 17 that is
not comprised in the new SACK, the previous SACK can thus
not be removed.

Additionally the SACKs in an output queue can be sorted as
10 to redundant SACKs and blocks, this is especially
advantageous in the cases when a previous SACK cannot be
removed. According to the invention this can be done in
two different ways. In a first output queue redundancy
sorting, all the blocks of the SACKs in the queue are put
15 in a separate place/queue where all the redundant blocks
are removed, whereafter new SACKs are put together with the
remaining non-redundant blocks and put into the output
queue. A newly triggered SACK is preferably not stripped
of its blocks but only used for the determination of which
20 blocks are redundant. In a second, and preferred, output
queue redundancy sorting, the blocks of the SACKs in the
output queue are compared to thus be able to remove SACKs
that are completely redundant.

25 Figure 2 shows a flow chart of a method according to the
invention. A first step 210 awaits the
generation/triggering of a new SACK. When a new SACK has
been generated to be transmitted back to a sender then the
procedure determines in a second step 220 if there is any
30 previous SACKs in an output queue which comprises SACKs to
be transmitted back to the sender. If there are no SACKs
in the output queue then the procedure continues with a
third step 230 that simply adds the new SACK to the output
queue, whereafter the procedure returns to the first step
35 210. In the second step 220 if it is instead determined

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that there is a previous SACK in the output queue, then the
procedure continues with a fourth step 240. The fourth
step 240 compares the contents of the new SACK with the
contents of the previous SACK, more specifically the number
5   of blocks in the two SACKs are compared. If the two SACKs
have the same number of blocks then the procedure continues
with a fifth step 250, and if they have a different number
of blocks then the procedure continues with a sixth step
260. The fifth step 250 also compares the contents of the
10 new SACK with the contents of the previous SACK, more
specifically in this step the contents of the two SACKs are
compared to determine if there has been a block shift. If
there has been a block shift then the procedure continues
with a seventh step 270, otherwise, if there has not been
15 a block shift, then the procedure continues with the sixth
step 260. The sixth step 260 removes the previous SACK
from the output queue, adds the new SACK to the output
queue and then the procedure continues with the first step
210. The seventh step 270 adds the new SACK to the output
20 queue and then attempts to remove redundant blocks from the
SACKs in the output queue by sorting and removing either
just redundant blocks or by removing redundant SACKs.
Thereafter the procedure continues with the first step 210.

25 Figure 3 shows the layered data communication architecture
of an information consumer according to the invention. A
layer refers to a process or a device inside a computer
system, which is designed to perform a specific function.
An application 310 is for our purposes the information
30 consumer that requests downloads of data information, for
example. These requests are forwarded to the Transmission
Control Protocol (TCP) layer 320, then to the Internet
Protocol (IP) 330, down via interfaces such as modems with
Point-to-Point Protocols (PPP) 340 or Ethernet 350 to
35 output lines 360. The requested information will,

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hopefully, after a while appear on the input lines 370 and transported through all the layers up to the application layer 310. SACKs will then be sent back to the sender. The invention will work on any suitable output queue from the TCP layer 320 to after the link layer. Preferably the invention will sort away SACKS on the output queue 332 of the IP layer 330. It is normally not favourable to have the invention filter the SACKs after the data communication link layer since the the packets need to be unpacked which can be an extremely resource consuming measure due to for example the compression in the link layer 340, 350. The invention will then also be customized to one type of link layer 340, 350, i.e. if a switch is made from ethernet 350 to a PPP with a modem 340 then the system according to the invention has to be reconfigured.

The present invention can be put into apparatus-form either as pure hardware, as pure software or as a combination of hardware and software. If the method according to the invention is realised in the form of software, it can be completely independent or it can be one part of a larger program. The software can suitably be located in a general purpose computer, in a dedicated computer, or a distributed combination thereof.

As a summary, the invention can basically be described as a method of improving the throughput in asymmetrical networks by removing/filtering in an efficient manner completely redundant SACKs only.

The invention is not limited to the embodiments described above but may be varied within the scope of the appended patent claims.

14

5   FIG 1
    110   information source/provider
    120   arbitrary network such as internet
    130   gateway
    140   high speed downlink
10 150   information consumer
    155   output queue
    160   gateway
    170   slow uplink
    180   gateway
15
    FIG 2
    210   determine if there is a new SACK
    220   determine if there is a previous SACK in the
                output queue
20 230   add new SACK to output queue
    240   compare content as to the same number of blocks
    250   compare content as to if there is a block shift
    260   remove previous SACK from output queue
    270   add new SACK to output queue and sort SACKs in
25   output queue

    FIG 3
    310   application layer
    320   TCP layer
30 330   IP layer
    332   IP layer output queue with SACKs
    340   PPP
    350   Ethernet
    360   output lines
35 370   input lines

15

5   CLAIMS

1.   A method of, when receiving information in a network
that transports information according to the general
principles of the Transmission Control Protocol (TCP),
10   reducing the number of selective acknowledgements (SACK) to
be transferred to a sender, **characterized in that** the
method comprises the following steps when a new selective
acknowledgement has been generated:
-    determining if there is a previous selective
15   acknowledgement in a queue to be transferred to the
sender, and if there is a previous selective
acknowledgemnt in the queue then further performing
the following additional steps;
-    comparing the content of the new selective
20   acknowledgement with the content of the
previous selective acknowledgement;
-    removing the previous selective acknowledgement
from the queue in dependence on the result of
the comparison.
25

2.   The method according to claim 1, **characterized in that**
in the additional step of removing the previous selective
acknowledgement from the queue, the previous selective
acknowledgement is removed from the queue if the previous
30   selective acknowledgement has a different number of blocks
than the new selective acknowledgement.

3.   The method according to claim 1 or 2, **characterized
in that** in the additional step of removing the previous
35   selective acknowledgement from the queue, the previous

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selective acknowledgement is removed from the queue if the previous selective acknowledgement has the same number of blocks as the new selective acknowledgement and if only the right edge of the first block is different between the

5   previous selective acknowledgement and the new selective acknowledgement.

4.   The method according to any one of claims 1 to 3, **characterized in that** the method further comprises the

10   additional step of:
-   sorting the selective acknowledgements in the queue as to which blocks are redundant.

5.   The method according to claim 4, **characterized in that**

15   the step of sorting comprises the following block sorting steps:
-   disassembling   into   blocks   the   selective acknowledgements that have not been transferred to a sender;

20   -   removing redundant blocks;
-   assembling the remaining blocks into block sorted selective acknowledgements;
-   placing the block sorted selective acknowledgements into the queue.

25

6.   The method according to claim 4, **characterized in that** the step of sorting comprises the following selective acknowledgement steps:
-   comparing the selective acknowledgements that have not

30   been transferred to a sender;
-   removing the redundant selective acknowledgements.

7.   The method according to any one of claims 4 to 6, **characterized in that** the step of sorting is performed only

35   if the previous selective acknowledgement has not been

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removed from the queue.

8.   The method according to any one of claims 1 to 7,
characterized in that the method is performed on a queue in
5 any suitable layer from the TCP layer to after the link
layer.

9.   The method according to claim 8, **characterized in that**
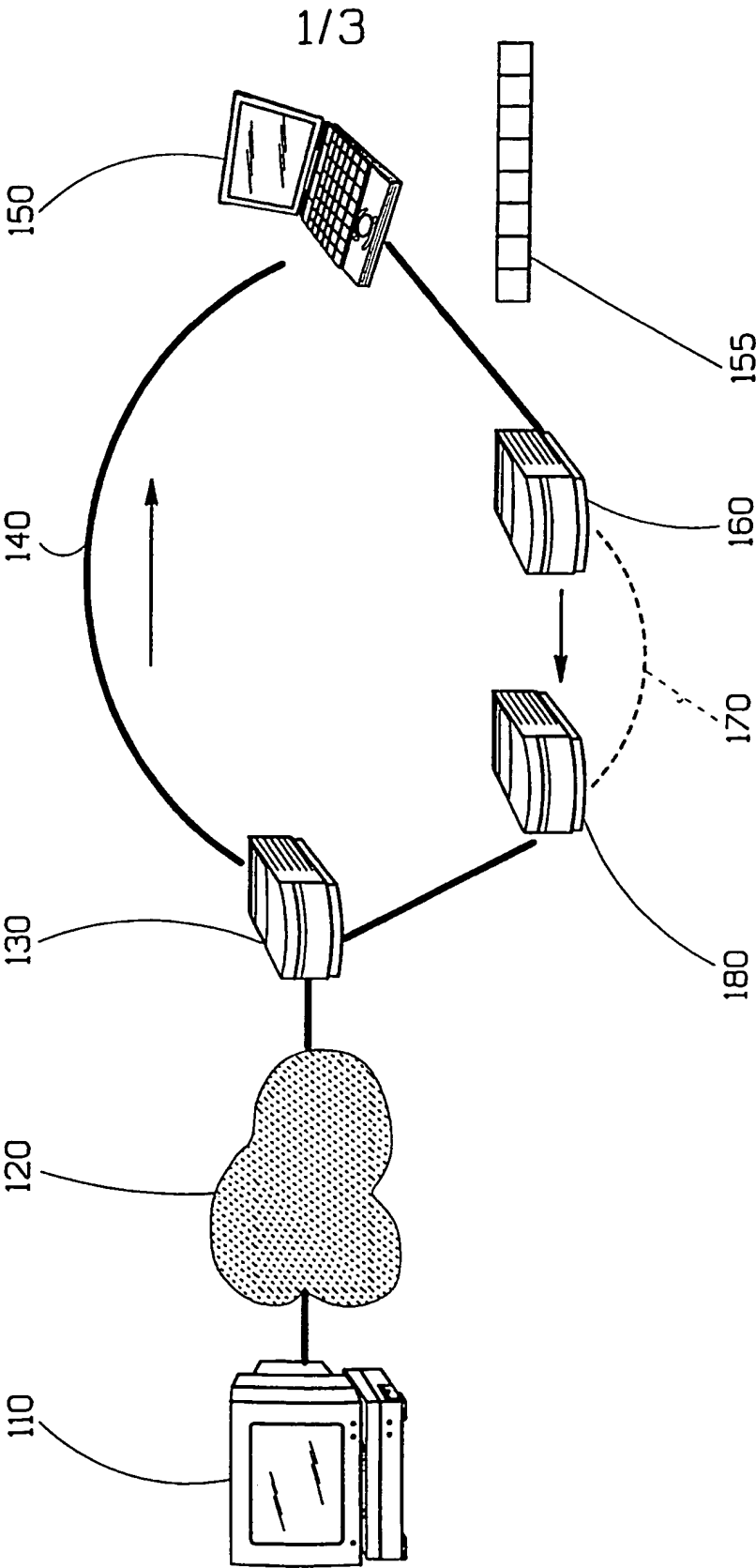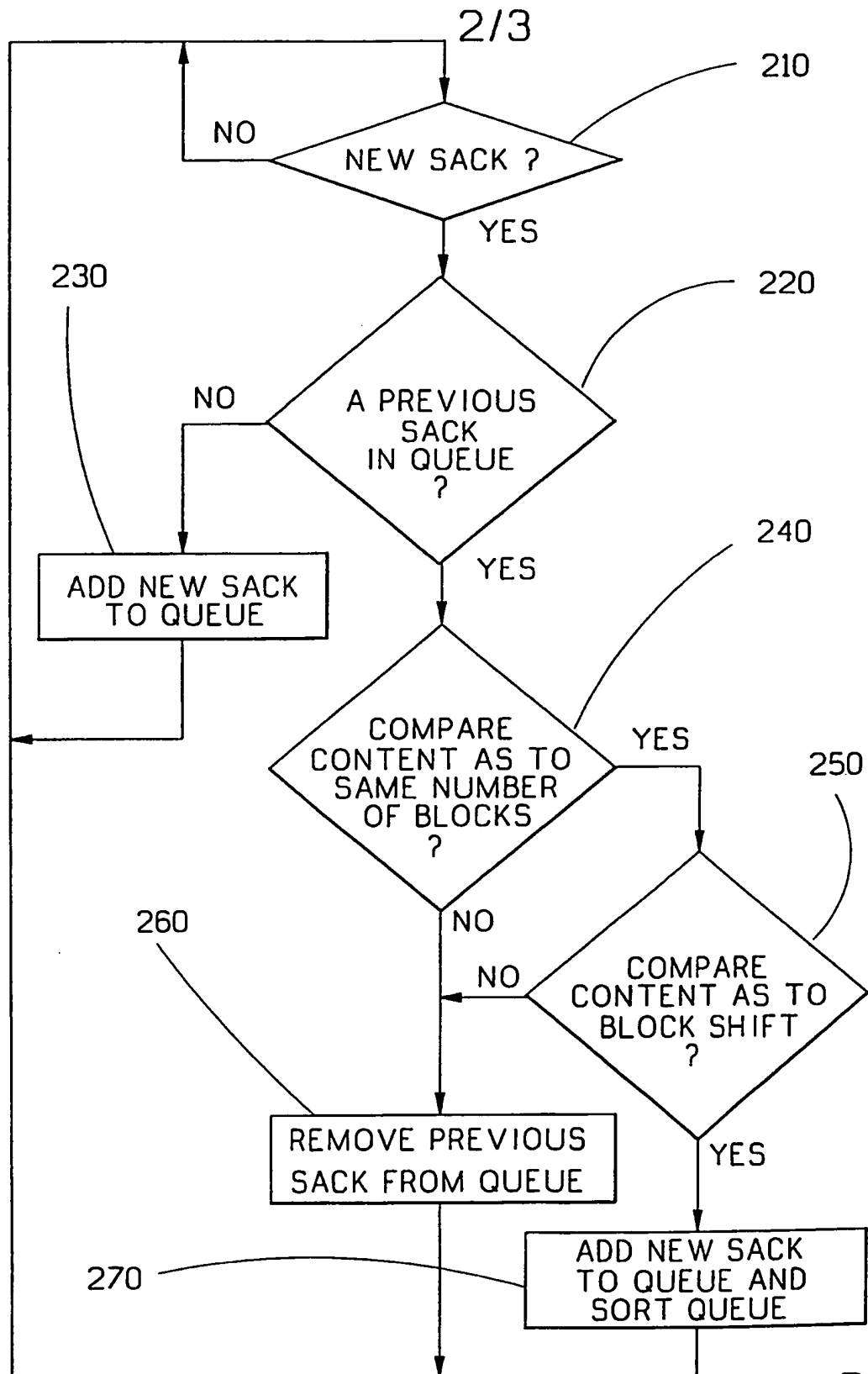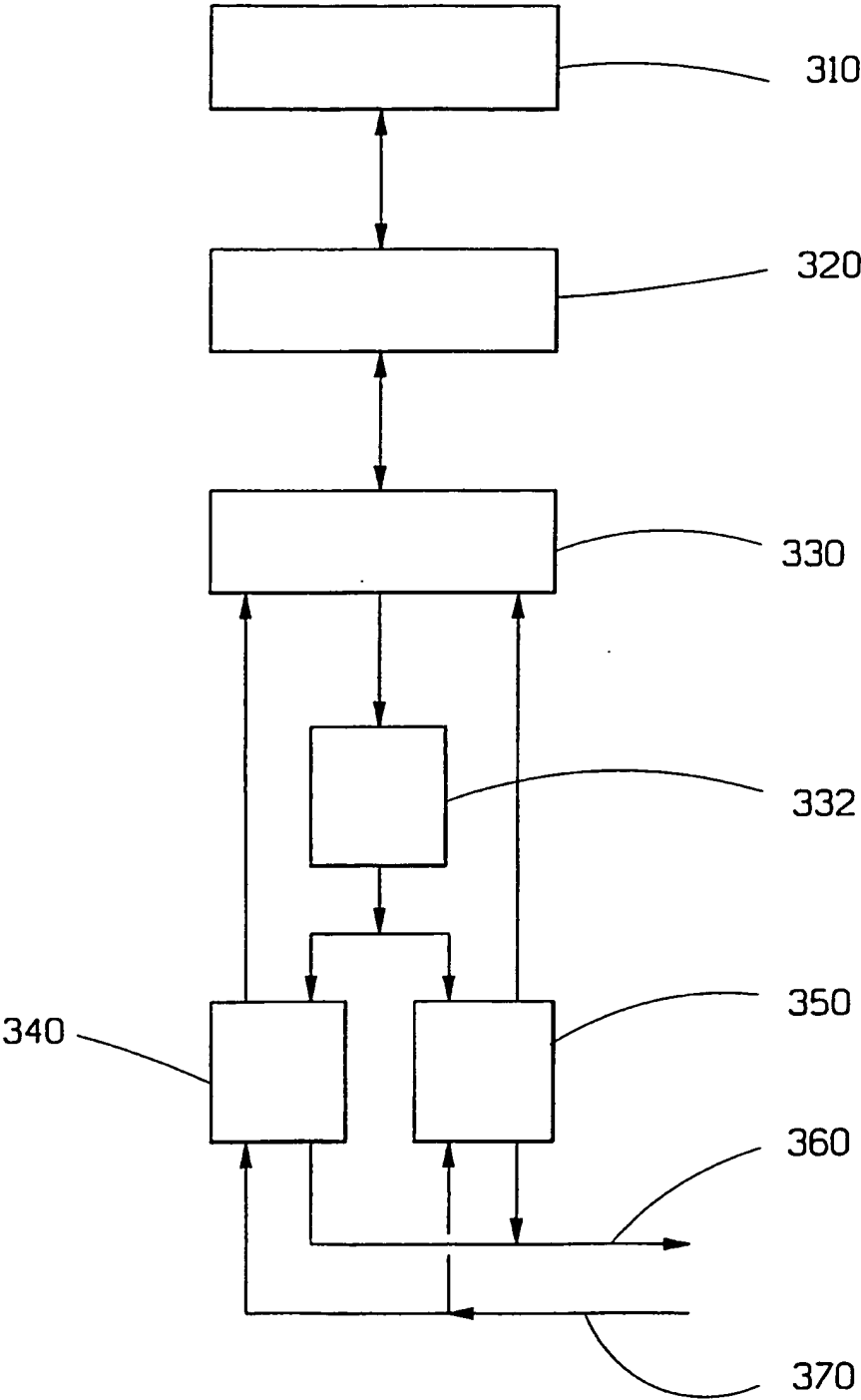the method is performed on the internet protocol layer
10 output queue.

1/3

FIG.1

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FIG.2

FIG.3

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: H04Q 11/04, H04L 1/00, H04L 29/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: H04Q, H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 9837670 A1 (AT & T CORP.), 27 August 1998 (27.08.98), page 4, line 12 - page 6, line 28; page 18, line 1 - page 20, line 28, claims 1,7,8, 16-20, abstract	1-9
A	N.SAMARAWEERA ET AL:"Integration of Internet Traffic with Digital Video Broadcasting"; UK Teletraffic Symposium (UKTS), IEEE, 1998. See section 4-5, abstract.	1-9

[X] Further documents are listed in the continuation of Box C.   [X] See patent family annex.

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17 October 2000	1 8 -10- 2000

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Form PCT/ISA/210 (second sheet) (July 1992)

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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